Cooling, Heating, and Power (CHP)
Conserving resources and reducing emissions

THE BENEFITS
- Increases energy efficiency by 30% or more
- Reduces greenhouse gas emissions
- Uses previously wasted heat
- Improves indoor air quality by managing humidity
- Prevents blackouts and brownouts
- Improves power quality and enhances grid reliability
- Increases control over building conditions

TECHNOLOGIES
- Power Generation
  - Engines
  - Microturbines
  - Combustion turbines
  - Fuel cells
- Thermally Activated Technologies
  - Absorption chillers
  - Desiccant dehumidification
  - Humidification
  - Heating
  - Domestic hot water
  - Steam turbines
  - Thermal storage
- Electric heating, ventilation, and air-conditioning systems
- Hybrid fuel cell/microturbine systems
- Hybrid CHP/renewable technologies

What Is CHP?
Cooling, heating, and power (CHP) systems integrate various types of power generation equipment with thermally activated technologies such as desiccant dehumidification, absorption cooling, and heating. The integration of these systems allows productive use of thermal energy that is created during power generation, which would otherwise be discarded.

How Does It Work?
CHP is not a single technology but an integrated array of technologies that take advantage of recovered heat. A CHP system in a facility might generate electrical power using equipment such as an engine, microturbine, or fuel cell; cool with one or more electric or gas chillers; and heat water using hot exhaust from the power-generating equipment.

Conventionally, electrical power is produced at generating plants far removed from the power users. Much of the heat that is a by-product of power generation is discarded to the environment. CHP systems can generate power where it is used and "recycle" the by-product heat for services such as space cooling/heating, humidity control, and water heating. Heat produced by conventional cooling systems also typically is vented to the outdoors. CHP systems transfer heat produced by cooling equipment to other system components that need heat; for example, hot exhaust from a direct-fired absorption chiller can be used to regenerate a desiccant wheel.

Integrated CHP systems are best suited to facilities with large cooling loads; those with balanced, simultaneous demands for electricity and thermal energy; or cases where multiple pieces of equipment are required and the CHP system can be thermally and electrically balanced.

What Are the Benefits?
CHP systems can conserve energy and reduce emissions at the same time that they can improve indoor air quality through humidity control and allow owners greater control over building conditions and power demands. A CHP system can increase the energy efficiency of a facility by 30% or more and reduce CO_2 emissions by 45% or more. Increased use of desiccant dehumidification, using waste heat to regenerate the desiccant, provides healthier living and working conditions. The reduced demand on utility systems improves the reliability of distribution systems and helps reduce peak-time blackouts or brownouts.

CHP systems can offer increased power quality and high reliability required by modern data centers that will move our digital economy forward.

What Is the Market Potential?
CHP is gaining momentum in the marketplace. The Electric Power Research Institute expects that 20 to 40% of all new power generation will result from distributed generation, much of that from CHP technology. The Department of Energy envisions that by 2020, CHP will be the preferred method of energy use in buildings.

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Chiller Technology

Chiller prototype will be field tested in Vegas

THE BENEFITS

- ***Reduces the electrical demand for cooling***
- ***Eliminates the use of ozone-depleting refrigerants***
- ***Reduces peak energy demand***
- ***Increases energy efficiency***
- ***Reduces harmful emissions***
- ***Improves U.S. competitiveness***

What Is the Triple-effect Chiller?

Large commercial buildings are usually air-conditioned by circulating chilled water through air handlers and fan coil units. The chilled water is produced by equipment (called water chillers) that removes heat from the returning water and rejects that heat to the atmosphere. The technical challenge in improving chiller design is finding the most economical and environmentally safe method to produce chilled water. Absorption chillers using natural gas offer building owners the option of fuel choice (gas or electricity) to better manage building energy requirements. The first absorption chillers were single-effect systems, which use a cycle consisting of an evaporator, an absorber, a generator, and a condenser. Double-effect chillers, incorporating a second generator and condenser, were introduced in the 1950s. Triple-effect chillers are just now emerging from the laboratory.

What Are Its Advantages?

Gas-fired triple-effect technology offers benefits to consumers, utilities, and the environment. A 450-ton prototype triple-effect unit was laboratory-tested during 1998 and 1999 and proved to be at least 30% more efficient than double-effect chillers now on the market. It uses an environmentally benign lithium bromide and water solution as a coolant, rather than ozone-depleting chlorinated refrigerants. In addition, its emissions of carbon dioxide, sulfur dioxide, and particulates are lower than those from double-effect chillers.

The Clark County Government Center in Las Vegas will field test a triple-effect chiller developed by ORNL, York, and Rocky Research.

Model of the triple-effect chiller that will be tested in the Clark County government building.

The energy-saving technology offers gas and electric utilities opportunities to reduce peak electricity demand and use fuel more efficiently through resource planning and management of demand for power. This technology offers energy efficiency and economic payback to owners, and job creation and improved competitiveness in international markets to the nation.

Triple-effect chillers are a thermally activated cooling technology that can also be incorporated in integrated CHP systems.

What Is the Status of the Research Effort?

A 450-ton-capacity, natural gas–powered triple-effect chiller will be field tested in the hot, dry climate of Las Vegas, Nevada. The chiller will be installed in the Clark County Government Center—a six-story building of more than 380,000 ft^2—in the summer of 2001. The field test will continue for 12 to 18 months, during which the efficiency and effectiveness of the chiller will be monitored by ORNL researchers.

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Desiccant Dehumidification

Active humidity control improves indoor air quality

THE BENEFITS

- **Allows independent control of humidity and temperature**
- **Reduces microbial and fungal growth associated with sick building syndrome**
- **Provides comfort during humid weather and under conditions when conventional HVAC is not controlling humidity**
- **Reduces peak electrical demand**
- **Allows use of waste heat for latent load control**
- **Makes use of recovered energy that is critical to achieving 70% resource efficiency with CHP systems**

Why the Interest in Desiccant Dehumidification?

Desiccant-based dehumidification can help solve humidity problems in commercial, institutional, and eventually residential buildings. Conventional heating, ventilating, and air-conditioning (HVAC) systems dehumidify inefficiently and ineffectively.

Breakthroughs in desiccant materials and equipment technologies are making desiccant air-conditioning more cost-effective at the same time that interest in indoor air quality (IAQ) is increasing.

American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) Building Standard 62-1999 requires significant outside air to ventilate many commercial and public buildings. Desiccant dehumidification can help existing HVAC systems manage the moisture emanating from the greater influx of humid fresh air.

How Does It Work?

Desiccants are materials that adsorb water vapor. A solid desiccant dehumidifier usually uses a corrugated wheel coated with a desiccant material; the wheel rotates between the fresh air stream used for ventilation and warm air used to regenerate (dry) the desiccant. The dehumidified air is cooled or heated, if necessary, and then circulated within the building.

What Are Its Benefits?

Desiccant dehumidification allows independent control of temperature and humidity. A desiccant system can dehumidify air without cooling it. If cooling is needed, the dry air is easier to cool and feels comfortable at a higher temperature. Thus desiccant dehumidification reduces the dehumidification work of the HVAC system, saving energy and allowing the use of a smaller, less costly air-conditioning system.

Active humidity control also improves IAQ. Excess moisture encourages the growth of microorganisms that lead to respiratory illnesses and "sick building syndrome." Desiccant air conditioning maintains humidity in the 45 to 50% range and minimizes the growth of pathogens.

Supermarkets, hospitals, schools, and shopping malls are particulary well suited to desiccant dehumidification.

What Is Its Market Potential?

Desiccant dehumidification is gaining ground in a number of markets: supermarkets, hotels and dormitories, schools, nursing homes and hospitals, and large retail outlets.

A study sponsored by Oak Ridge National Laboratory (ORNL) indicates there is a $150 million potential annual market for HVAC systems that include desiccant dehumidification. (Desiccant-Based Preconditioning Market Analysis, ORNL/SUB/94-SU044/1. Available at www.ornl.gov/ornl/btc/desiccant.html)

Who Is Researching Desiccant Technologies?

Research and development on desiccant technologies and applications is being funded by the U.S. Department of Energy (DOE), the Gas Technology Institute, utilities, and HVAC equipment manufacturers. ORNL and the National Renewable Energy Laboratory manage the desiccant technology federal research program for DOE.

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Ammonia-Water Absorption

Prototypes show dramatic gains in heating effficiency

THE BENEFITS

- **Uses an environmentally benign working fluid**
- **Reduces energy consumption**
- **Reduces peak demand on utilities**
- **Reduces carbon emissions from power plants**

What Is an Ammonia-Water Absorption Heat Pump?

Researchers have been working for several years to develop an advanced heat pump, powered by thermal energy, that could save energy needed to heat and cool buildings. The ammonia-water absorption heat pump uses an advanced technology to heat and cool air that is more efficient and environmentally friendly than conventional heat pumps.

What Are the Benefits?

A key environmental advantage of the ammonia-water cycle is that it uses an environmentally benign mixture as a cooling fluid, rather than refrigerants that deplete the ozone layer. Because absorption heat pumps use less power, they will reduce carbon emissions from fossil fuels burned in power plants. For consumers, the energy efficiency of the absorption cycle will mean lower energy bills. For utilities, the new technology will help to reduce seasonal peak demands on the electricity system.

Who Are the Research Partners?

The basic ammonia-water absorption heat pump technology and the first working prototypes were developed principally under Department of Energy (DOE) sponsorship under a subcontract directed by Oak Ridge National Laboratory (ORNL). DOE and the natural gas industry, with their manufacturing partners, have combined their financial and technical resources to complete the development and commercialization of the ammonia-water absorption heat pump.

The ammonia-water absorption heat pump tested at ORNL.

What Is the Status of the R&D Effort?

A 5-ton operating prototype of the heat pump was built in 1999. A prototype ammonia-water absorption heat pump has been tested at ORNL to evaluate its performance. This unit consists of a prototype absorption heat pump outdoor assembly coupled with an off-the-shelf indoor chiller fan coil. Under standard industrial testing conditions, it has been 33% more efficient than the best existing gas furnace. A complete ammonia-water absorption unit should be even more efficient. Testing of additional prototypes from the Ammonia-Water Absorption Venture will continue in 2001.

Introduction of high-efficiency, competitively priced units to the consumer market is expected over the next two years.

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Hi-Cool Absorption Cycle

Next-generation absorption refrigeration systems and heat pumps

THE BENEFITS

- **Increases the cooling efficiency of ammonia-water heat pumps**
- **Expands the market range for ammonia-water heat pumps to southern latitudes**

Why Is Hi-Cool Needed?

"Hi-Cool" refers to advanced cooling cycles designed to increase the cooling efficiency of the current absorption technologies. Researchers have developed natural gas–fueled absorption systems that use ammonia-water as the working fluid. In laboratory tests, the heating efficiency of the gas-fired unit was 33% better than that of the best conventional gas furnace. For cooling, however, the gas-fired ammonia-water absorption unit is comparable to a mid-line air conditioner. New technology with higher efficiency and increased versatility is needed to expand the market for the basic ammonia-water systems. Development of a successful Hi-Cool cycle would greatly expand the market range of gas-fired absorption systems. Hi-Cool is also expected to work well in rooftop commercial units, where annual cooling loads are greater than for residences.

What Is the Goal?

The goal of Hi-Cool research is the development of systems that are more energy-efficient than current cooling technologies (with a potential for even higher heating efficiency, also). Technologies being explored to reach that goal include higher-efficiency cycles and fluids.

What Is the Status of the R&D Program?

Researchers have selected the cycles with the best potential for achieving the project goals, and critical components of the system have been developed. A Hi-Cool refrigeration heat-pump prototype will be developed to demonstrate the technical feasibility and performance potential of the preferred cycle. Then a small number of packaged prototype Hi-Cool units will be designed, fabricated, tested, and developed. A manufacturing cost study and market potential study will be conducted based on the final prototype design. These prototypes will be used for engineering test evaluation, for quality/reliability testing, and for demonstration to potential manufacturers and marketers of light commercial/residential gas absorption refrigeration systems and heat pumps. (A manufacturing partner will be involved in the later phases.)

Hi-Cool packaged unit being developed by Energy Concepts.

What Hi-Cool Cycles Are Being Tested?

Two new Hi-Cool technologies are being developed. The first cycle is based on a Hi-Cool concept that uses an ammonia–water mixture. It will be used in an 8-ton light commercial unit. The second system will be based on a Hi-Cool inorganic salts-ammonia sorption cycle and be used in a 3-ton unit. These units will be tested in-house, where initial tests and subsequent performance tests will be performed. Then they will be available for testing by independent entities. Testing of Hi-Cool prototypes should start in 2001–2002, and introduction to the marketplace should occur in 2004–2005.

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